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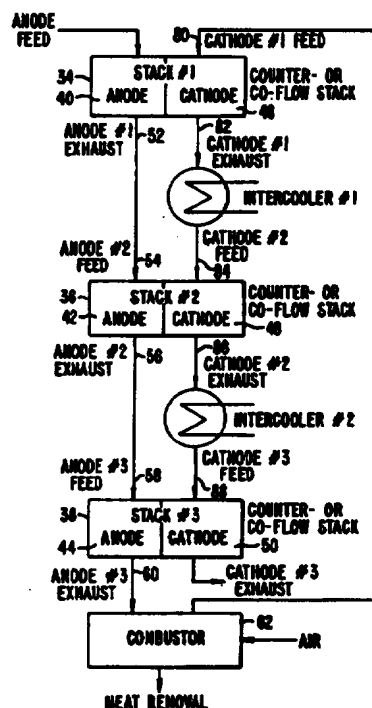
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## (57) Abstract

The invention provides a molten carbonate fuel cell system having a plurality of fuel cell stacks (34, 36, 38) with each fuel cell stack having an anode (40, 42, 44) and a cathode (46, 48, 50). Each of the anodes includes a cathode feed inlet and a cathode exhaust outlet. A combustor for receiving unreacted fuel from the anode exhaust outlet of a first one of the fuel cell stacks (60) is connected to the cathode feed inlet of a second one of the fuel cell stacks (80) for delivering exhaust from the combustor. An intercooler is disposed between the cathode exhaust outlet of the second fuel cell stack (86) and the cathode feed inlet of the first fuel cell stack (88) for cooling gases passing therebetween.



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## THERMAL INTEGRATION OF AN AIR-COOLED FUEL CELL STACK

### BACKGROUND OF THE INVENTION

The invention is related to fuel cell systems that utilize gas recirculation for fuel cell stack temperature control, and in particular to molten carbonate fuel cell (MCFC) systems.

A fuel cell consists of two distinct reacting chambers commonly referred to as the anode and cathode. Fuel cell systems are constructed of multiple fuel cells operating in parallel and connected electrically in series. The multiple fuel cells are typically combined into one operating unit with the appropriate gas manifolding to form what is commonly referred to as a fuel cell stack.

Fig. 1 illustrates a schematic view of a conventional MCFC system 10. In the MCFC system 10, reformed fuel is delivered to an anode 14 of a fuel cell stack 16 through an anode feed inlet 12 where it reacts with carbonate ions to produce carbon dioxide, water, and electricity. Typically, 70% to 85% of the fuel heating value is consumed in the anode 14. Downstream from the anode 14, the remaining unreacted fuel is delivered to a combustor 18 through an anode exhaust outlet 20. The unreacted fuel is burned in the combustor 18 to produce carbon dioxide and water. Oxygen is supplied to the combustor 18 and may be either air and/or cathode exhaust gases. Various heat integration schemes have been proposed for recuperating both the heat in the cathode exhaust and the heat liberated in the combustor 18 for various purposes such as preheating, steam generation, and supplying the heat required for reforming fuel. The combustor exhaust is mixed with excess air and sent to a cathode 22 of the fuel cell stack 16 through a cathode feed inlet 24 where carbon dioxide and oxygen are reacted to regenerate the carbonate ions consumed at the anode 14.

The overall reaction in the fuel cell stack 16 is that of combustion. Heat is generated in the stack 16 through the heat of reaction of fuel as well as heat generated through ohmic losses. A typical fuel cell system utilizes  
5 recirculation of cooled cathode exhaust gases in order to control the fuel cell stack temperature. In some systems, anode gas recirculation is also used. The cathode exhaust gases are recirculated through a cathode exhaust outlet 26 and are directed through a recycle cooler 28. A recycle blower 30  
10 is also used to recirculate the gas. The recycle blower 30 introduces various problems and limitations including decreased reliability, increased maintenance, increased auxiliary power consumption, increased plot space, and increased noise. In addition, recirculation of gases leads to  
15 larger gas flows and therefore larger diameter piping between the fuel cell stack 16 and the balance of plant.

#### SUMMARY OF THE INVENTION

According to the invention, a MCFC system is  
20 provided having a plurality of fuel cell stacks. Each fuel cell stack includes an anode and a cathode, with each anode having an anode feed inlet and an anode exhaust outlet, and each cathode having a cathode feed inlet and a cathode exhaust outlet. The system includes a combustor for receiving  
25 unreacted fuel from the anode exhaust outlet of a first one of the fuel cell stacks. The combustor is connected to the cathode feed inlet of a second one of the fuel cell stacks for delivering exhaust from the combustor to the second fuel cell stack. An intercooler is provided between the cathode exhaust  
30 outlet of the second fuel cell stack and the cathode feed inlet of the second fuel cell stack for cooling gases passing therebetween.

In another embodiment, a MCFC system is provided having a plurality of fuel cell stacks with each fuel cell  
35 stack having an anode and a cathode. Each anode includes an anode feed inlet and an anode exhaust outlet, and each cathode includes a cathode feed inlet and a cathode exhaust outlet. A combustor is provided for receiving the reacted fuel from the

anode exhaust outlet of a first one of the fuel cell stacks. The combustor is connected to the cathode feed inlet of the first fuel cell stack for delivering exhaust from the combustor. An intercooler between the cathode exhaust outlet of the first fuel cell stack and the cathode feed inlet of a second fuel cell stack is provided for cooling gases passing between the fuel cell stacks.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a schematic view of a conventional MCFC system.

Fig. 2 illustrates one embodiment of a MCFC system according to the present invention.

Fig. 3 illustrates an alternative embodiment of a MCFC system according to the present invention.

Fig. 4 illustrates a plant configuration using a MCFC system according to the present invention.

#### DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Shown in Fig. 2 is one embodiment of a MCFC system 32 according to the invention. The system 32 includes three fuel cell stacks 34, 36, and 38. Although three fuel cell stacks are illustrated, the number of stacks in the system can be varied depending upon the cost and operability.

Each of the stacks 34, 36, and 38 have an anode 40, 42, 44, respectively, and a cathode 46, 48, and 50, respectively. Gases from the anode 40 pass through an anode exhaust outlet 52 and enter into anode 42 through an anode feed inlet 54. In a similar manner, gases from anode 42 exit through exhaust outlet 56 and enter anode 44 through anode feed inlet 58. Gases are exhausted from anode 44 through an anode exhaust outlet 60 and into a combustor 62.

Countercurrent to the gasses delivered through the anodes 40, 42, 44, gases are passed through each of the cathodes 50, 48, and 46. Gases from the combustor 62 are enter the cathode 50 through a cathode feed inlet 64. Exhaust from cathode 50 exits through a cathode exhaust outlet 66 and enters cathode 48 through a cathode feed inlet 68. In a

similar manner, gases from cathode 48 are exited through cathode exhaust outlet 70 and pass into cathode 46 through cathode feed inlet 72. With this arrangement, the anode and cathode gases pass countercurrently between the three stacks 34, 36, and 38 as indicated by the arrows in Fig. 2. Within each of the stacks 34, 36, and 38, the anode and cathode gases may flow either countercurrently or co-currently, depending on the preferred operating conditions for the stacks. Disposed between the stack 38 and the stack 36 is an intercooler 74 for cooling the gases exhausted from cathode exhaust outlet 66. Another intercooler 76 is disposed between the stack 36 and the stack 34 to cool gases exhausted through cathode exhaust outlet 70.

By configuring the stacks 34, 36, and 38 in this manner, the use of a recycle blower can be eliminated. Elimination of the recycle blower leads to a variety of benefits including: increased reliability, decreased maintenance, decreased auxiliary power consumption, decreased plot space, decreased noise, and smaller diameter pipes between fuel cell stacks and the balance of plant. Another benefit of multiple fuel cell stacks is that the total electrical power increases with the number of stacks.

An alternative embodiment of a MCFC system 32' is shown in Fig. 3. The system 32' is constructed essentially identically to the system 32 of Fig. 2 except for the flow of gases between the cathodes 46, 48, and 50 and the connection of the combustor 62. Gases from the combustor 62 are directed into the cathode 46 through a cathode feed inlet 80, and gases exit from cathode 46 through a cathode exhaust outlet 82 where they enter the cathode 48 through a cathode feed inlet 84. In a similar manner, gases from cathode 48 exit through cathode exhaust outlet 86 and enter the cathode 50 through a cathode feed inlet 88. This configuration allows for the anode and cathode gases to pass co-currently between the stacks 34, 36, and 38. Within the stacks, gases may flow either countercurrently or co-currently.

Calculations were performed to assess the advantages of the invention as described in Figs. 2 and 3 compared to a

conventional system. Table 1 presents a summary of the stack operating conditions for the conventional system, the system 32 (alternative #1), and system 32' (alternative #2). The calculations are based on the following: fixed anode feed, 250 total cells, 80% anode fuel utilization overall, countercurrent flow within each stack, and 70% excess air overall. Within Table 1, stacks #1, #2, and #3 correspond to stacks 34, 36, and 38, respectively.

**TABLE 1**  
**COMPARISON OF MULTIPLE CELL STACK ALTERNATIVES**

		<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
<b>Configuration</b>				
Total Cells		250	250	250
Number of Stacks		1	3	3
Number of Cathode Intercoolers		0	2	2
Anode Flow Path		1	1,2,3	1,2,3
Cathode Flow Path		1	3,2,1	1,2,3
Cell Internal Configuration		Counter Flow	Counter Flow	Counter Flow
Anode Feed Steam-to-Carbon		3.5	3.5	3.5
<b>Stack Operating Conditions</b>				
<u>Anode Flow Rates</u>				
Anode #1	lbmol/hr	37.55	37.55	37.55
Anode #2	lbmol/hr		43.46	43.46
Anode #3	lbmol/hr		49.36	49.36
<u>Cathode Flow Rates</u>				
Cathode #1	lbmol/hr	468.83	131.42	149.13
Cathode #2	lbmol/hr		140.28	140.28
Cathode #3	lbmol/hr		149.13	131.42

			<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
	<u>Anode Utilization</u>				
	Anode #1	fract		0.2667	0.2667
	Anode #2	fract		0.3637	0.3637
5	Anode #3	fract		0.5716	0.5716
	Overall	fract	0.8000	0.8001	0.8001
	<u>Cathode Utilization</u>				
	Cathode #1	fract		0.4983	0.2495
10	Cathode #2	fract		0.3326	0.3328
	Cathode #3	fract		0.2495	0.4983
	Overall	fract	0.7487	0.7487	0.7487
	<u>Stack Voltage</u>				
15	Stack #1	volts/cell	0.706	0.781	0.811
	Stack #2	volts/cell		0.756	0.756
	Stack #3	volts/cell		0.722	0.682
20	<u>Stack Power</u>				
	Stack #1	kW d.c.		112.2	116.5
	Stack #2	kW d.c.		108.3	108.3
	Stack #3	kW d.c.		103.3	97.6
	Total	kW d.c.	304.1	323.8	322.4
25	<u>Stack Temperatures</u>				
	Anode #1 In	°F	1200	1200	1200
	Anode #1 Out	°F	1100	1100	1100
	Cathode #1 In	°F	1050	1050	1050
30	Cathode #1 Out	°F	1290	Not Calc.	1266 Low: Need to Optimize conversion per cell
	Anode #2 In	°F		1100	1100



			<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
	Anode #2 Out	°F		1100	1100
	Cathode #2 In	°F		1050	1050
	Cathode #2 Out	°F		Not Calc.	1282 Close to 1290 °F
5	Anode #3 In	°F		1100	1100
	Anode #3 Out	°F		1100	1100
	Cathode #3 In	°F		1050	1050
	Cathode #3 Out	°F		Not Calc.	1345 High: Need to Optimize conversion per cell
	<u>Stack #1 Anode Compositions</u>				
10	H2	mole fract.	0.5058	0.5058	0.5058
	CO	mole fract.	0.0836	0.0836	0.0836
	CO2	mole fract.	0.0669	0.0669	0.0669
	H2O	mole fract.	0.3362	0.3362	0.3362
	N2	mole fract.	0.0006	0.0006	0.0006
15	<u>CH4</u>	<u>mole fract.</u>	<u>0.0070</u>	<u>0.0070</u>	<u>0.0070</u>
	Total	mole fract.	1.0001	1.0001	1.0001
	<u>Stack #2 Anode Compositions</u>				
	H2	mole fract.		0.3144	0.3144
20	CO	mole fract.		0.0591	0.0591
	CO2	mole fract.		0.2067	0.2067
	H2O	mole fract.		0.4132	0.4132
	N2	mole fract.		0.0005	0.0005
	<u>CH4</u>	<u>mole fract.</u>		<u>0.0060</u>	<u>0.0060</u>
25	Total	mole fract.		0.9999	0.9999
	<u>Stack #3 Anode Compositions</u>				
	H2	mole fract.		0.1677	0.1677
	CO	mole fract.		0.0416	0.0416
30	CO2	mole fract.		0.3121	0.3121

			<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
	H2O	mole fract.		0.4729	0.4729
	N2	mole fract.		0.0004	0.0004
	<u>CH4</u>	<u>mole fract.</u>		<u>0.0053</u>	<u>0.0053</u>
	Total	mole fract.		1.0000	1.0000
5	<u>Stack #1 Cathode Compositions</u>				
	CO2	mole fract.	0.0901	0.0901	0.1586
	H2O	mole fract.	0.2598	0.2598	0.2290
	N2/Ar	mole fract.	0.5659	0.5659	0.4986
10	<u>O2</u>	<u>mole fract.</u>	<u>0.0842</u>	<u>0.0842</u>	<u>0.1138</u>
	Total	mole fract.	1.0000	1.0000	1.0000
	<u>Stack #2 Cathode Compositions</u>				
	CO2	mole fract.		0.1265	0.1265
15	H2O	mole fract.		0.2434	0.2434
	N2/Ar	mole fract.		0.5302	0.5302
	<u>O2</u>	<u>mole fract.</u>		<u>0.0999</u>	<u>0.0999</u>
	Total			1.0000	1.0000
20	<u>Stack #3 Cathode Compositions</u>				
	CO2	mole fract.		0.1586	0.0901
	H2O	mole fract.		0.2290	0.2598
	N2/Ar	mole fract.		0.4986	0.5659
	<u>O2</u>	<u>mole fract.</u>		<u>0.1138</u>	<u>0.0842</u>
25	Total	mole fract.		1.0000	1.0000
<b>Estimated Pressure Drops</b>					
Cell Pressure Drops Proportional to (Flow Rate/Cell (1.5))					
	Anode #1	Δpsi	0.10	0.52	0.52
30	Anode #1 to Anode #2	Δpsi		0.05	0.05
	Anode #2	Δpsi		0.65	0.65
	Anode #2 to Anode #3	Δpsi		0.05	0.05
	Anode #3	Δpsi		0.78	0.78

			<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
	Anode #3 to Combustor	$\Delta$ psi	0.05	0.05	0.05
	Combustor	$\Delta$ psi	0.30	0.30	0.30
	Combustor to 1st Cathode	$\Delta$ psi	0.05	0.05	0.05
5	1st Cathode	$\Delta$ psi	0.60	0.56	0.56
	1st Cathode to 1st Intercooler	$\Delta$ psi		0.05	0.05
	1st Intercooler	$\Delta$ psi		0.10	0.10
	1st Intercooler to 2nd Cathode	$\Delta$ psi		0.05	0.05
	2nd Cathode	$\Delta$ psi		0.51	0.51
10	2nd Cathode to 2nd Intercooler	$\Delta$ psi		0.05	0.05
	2nd Intercooler	$\Delta$ psi		0.10	0.10
	2nd Intercooler to 3rd Cathode	$\Delta$ psi		0.05	0.05
	3rd Cathode	$\Delta$ psi		0.46	0.46
	Total	$\Delta$ psi	1.10	4.38	4.38
15	<b>Estimated Pressure Profile</b>				
	Anode #1 Inlet	psia	44.00	44.00	44.00
	Anode #1 Outlet	psia	43.90	43.48	43.48
	Anode #2 Inlet	psia		43.43	43.43
20	Anode #2 Outlet	psia		42.78	42.78
	Anode #3 Inlet	psia		42.73	42.73
	Anode #3 Outlet	psia		41.95	41.95
	Combustor Inlet	psia	43.85	41.90	41.90
	Combustor Outlet	psia	43.55	41.60	41.60
25	Cathode #1 Inlet	psia	43.50	40.08	41.55
	Cathode #1 Outlet	psia	42.90	39.62	40.99
	Intercooler #1 Inlet	psia		40.23	40.94
	Intercooler #2 Outlet	psia		40.13	40.84
	Cathode #2 Inlet	psia		40.79	40.79
30	Cathode #2 Outlet	psia		40.28	40.28
	Intercooler #2 Inlet	psia		40.94	40.23
	Intercooler #2 Outlet	psia		40.84	40.13
	Cathode #3 Inlet	psia		41.55	40.08

		<u>Conventional</u>	<u>Alternative #1</u>	<u>Alternative #1</u>
	Cathode #3 Outlet	psia	40.99	39.62
Estimated Wet Seal Differential Pressures				
	Anode #1 In - Cathode #1 Out	$\Delta$ psi	1.10	4.38
5	Anode #1 Out - Cathode #1 In	$\Delta$ psi	0.40	3.40
	Anode #2 In - Cathode #2 Out	$\Delta$ psi	3.15	3.15
	Anode #2 Out - Cathode #2 In	$\Delta$ psi	1.99	1.99
	Anode #3 In - Cathode #3 Out	$\Delta$ psi	1.74	3.12
10	Anode #3 Out - Cathode #3 In	$\Delta$ psi	0.40	1.87

These results indicate that gas recirculation is not necessary for stack temperature control. The pressure drop for a three stack system is greater than that of a single stack system. The differential pressures between the anode and cathode side of the stacks can be minimized by using co-flow inside each stack and by using co-flow between the stacks.

The advantages of using multiple fuel stacks does not necessarily require distinct heat exchangers between the cell stacks. The heat removal may be incorporated within the fuel cell manifolding, between or within fuel cell stacks, and from both the anode and cathode gases. In addition, the invention is not limited to the method of stack cooling. Stack cooling may be through indirect heat transfer to cool gases and/or saturated steam or through heat transfer to an "indirect reformer" within the fuel cell stack.

Fig. 4 illustrates one embodiment of a plant configuration 90 utilizing a MCFC system according to the invention. In the plant 90, natural gas is desulfurized in a desulfurizer 92, preheated in a gas preheater 94, mixed with superheated steam from a superheater 96, and further preheated by a mixed feed preheater 98, and sent to a reformer R. An exemplary reformer is a reformer developed by IHI, Japan, where the heat required for reforming is supplied by burning residual fuel that is unconverted in the fuel cell. The

reformed gas is sent to an anode A of a MCFC stack 100 where the majority of the fuel is consumed (via oxidation) to produce electricity. Only a portion of the chemical energy of the reformed gas is converted to electrical energy in the fuel cell. The portion of chemical energy that is not converted to electricity is released as thermal energy (heat). This heat must be removed to avoid the fuel cell exceeding its maximum temperature.

Compressed air from an air compressor 102 provides the necessary cooling medium for heat removal from the stack 100. This is an improvement over the existing state of the art MCFC systems which use recycled cathode exhaust (and in some cases, anode exhaust also) to provide cooling for the fuel cell. In the prior art systems, recirculation of gas requires a recycle blower that operates at temperatures close to 1300°F. Such a blower adds additional expense, consumes electricity, i.e., lowers the plant efficiency, and increases plant downtime due to mechanical failures. Furthermore, large diameter piping is required to provide the necessary path for the recycled gas. The use of air cooling eliminates the need for gas circulation, thereby reducing the plant cost and increasing the overall plant electrical efficiency.

The compressed air exiting the fuel cell intercooler picks up additional energy from flue gas exiting an expander/generator 106, and then flows to a combustor CO. The hot compressed air supplies the oxygen necessary for combustion of the anode exhaust. The combustor exhaust gas flows to the fuel cell cathode C where carbon dioxide and oxygen are consumed. The cathode exhaust gas flows to the expander/generator 106, which recovers some of the energy in the cathode exhaust to produce electricity. The expander exhaust gas provides heat to the compressed air and flows to a heat recovery steam generator (HRSG) 108. The HRSG 108 recovers heat from the processed flue gas for the following purposes: (1) preheating incoming boiler feed water in an economizer 110; (2) generating saturated steam in a boiler 112; (3) heating saturated steam in the superheater 96;

(4) preheating desulfurized natural gas in the gas preheater 94; and (5) preheating mixed natural gas and superheated steam in the mixed feed preheater 98.

Alternative heat integration schemes may employ some  
5 or all of the following process options: (1) The use of a  
turbocharger/generator system in place of a separate air  
compressor and expander/generator. (2) The placement of the  
startup burner on the compressed air line between the  
10 compressor discharge and the cell intercooler inlet. (This  
option can eliminate the need for electric startup heaters at  
the inlet of the fuel cell anode and cathode.) (3) The  
relocation of the compressed air/flue gas heat exchanger from  
downstream of the cell intercooler to upstream of the  
15 intercooler. This option increases the amount of heat  
recoverable from the expanding exhaust and increases the  
temperature of compressed air entering the intercooler  
(desirable for protecting the fuel cell electrolyte from  
freezing). This heat exchanger is preferably integrated into  
the HRSG.

20 The present invention has been described in detail  
for purposed of clarity and understanding. It is understood  
that this invention is not confined to the specific  
instruction described herein, but it encompasses modified  
forms within the scope of the following claims.

**WHAT IS CLAIMED IS:**

1. A molten carbonate fuel cell system, comprising:  
a fuel cell having an anode and a cathode, with the anode having an anode feed inlet and an anode exhaust outlet, and with the cathode having a cathode feed inlet and a cathode exhaust outlet, the fuel cell further including an intercooler for channeling the compressed air through the fuel cell;

means for supplying fuel to the anode feed inlet;

and

means for supplying compressed air to the heat removal means.

2. The system of claim 1, further comprising means for heating the compressed air prior to entering the heat removal means.

3. The system of claim 2, wherein the heating means includes a heat exchanger for transferring heat to the compressed air from gases circulated from the cathode exhaust outlet.

4. The system of claims 2, further comprising a combustor between the anode exhaust outlet and the cathode feed inlet, and wherein the compressed air is circulated from the fuel cell and to the combustor.

5. The system of claim 4, wherein gases exhausted from the anode exhaust outlet are circulated to the combustor.

6. A molten carbonate fuel cell system, comprising:  
a fuel cell having an anode and a cathode, with the anode having an anode feed inlet and an anode exhaust outlet, and with the cathode having a cathode feed inlet and a cathode exhaust outlet, the fuel cell further including heat removal means;

means for supplying fuel to the anode feed inlet;

means for supplying compressed air to the heat removal means; and

a heat exchanger which heats the compressed air prior to entering the heat removal means, said heat exchanger transferring heat to the compressed air from gases circulated from the cathode exhaust outlet.

7. The system of claim 6, further comprising a combustor between the anode exhaust outlet and the cathode feed inlet, and wherein the compressed air is circulated from the fuel cell and to the combustor.

8. The system of claim 7, wherein gases exhausted from the anode exhaust outlet are circulated to the combustor.

9. The system of claim 6, further comprising an intercooler which channels the compressed air through the fuel cell.

10. A process for operating a fuel cell power plant including a combustor and a fuel cell having an anode and a cathode, with the anode having an anode feed inlet and an anode exhaust outlet, and with the cathode having a cathode feed inlet and a cathode exhaust outlet, said process comprising:

supplying fuel to the anode through the anode feed inlet;

circulating exhaust from the anode exhaust outlet, through the combustor, and to the cathode feed inlet; and

supplying compressed air to an intercooler which channels the compressed air through the fuel cell to remove sufficient heat from the fuel cell to prevent overheating of the fuel cell.

11. The process of claim 10, further comprising heating the compressed air prior to supplying the compressed air to the fuel cell.



12. The process of claim 11, wherein the compressed air is heated by gases exhausted from the cathode exhaust outlet.

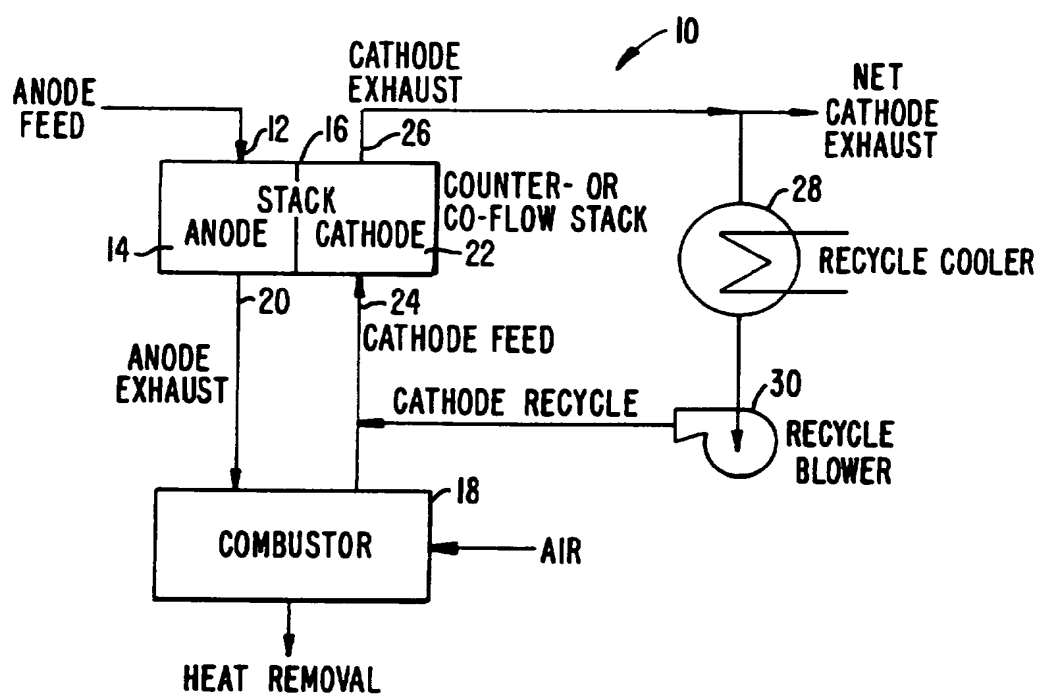
13. A process for operating a fuel cell power plant including a combustor and a fuel cell having an anode and a cathode, with the anode having an anode feed inlet and an anode exhaust outlet, and with the cathode having a cathode feed inlet and a cathode exhaust outlet, said process comprising:

supplying fuel to the anode through the anode feed inlet;

circulating exhaust from the anode exhaust outlet, through the combustor, and to the cathode feed inlet;

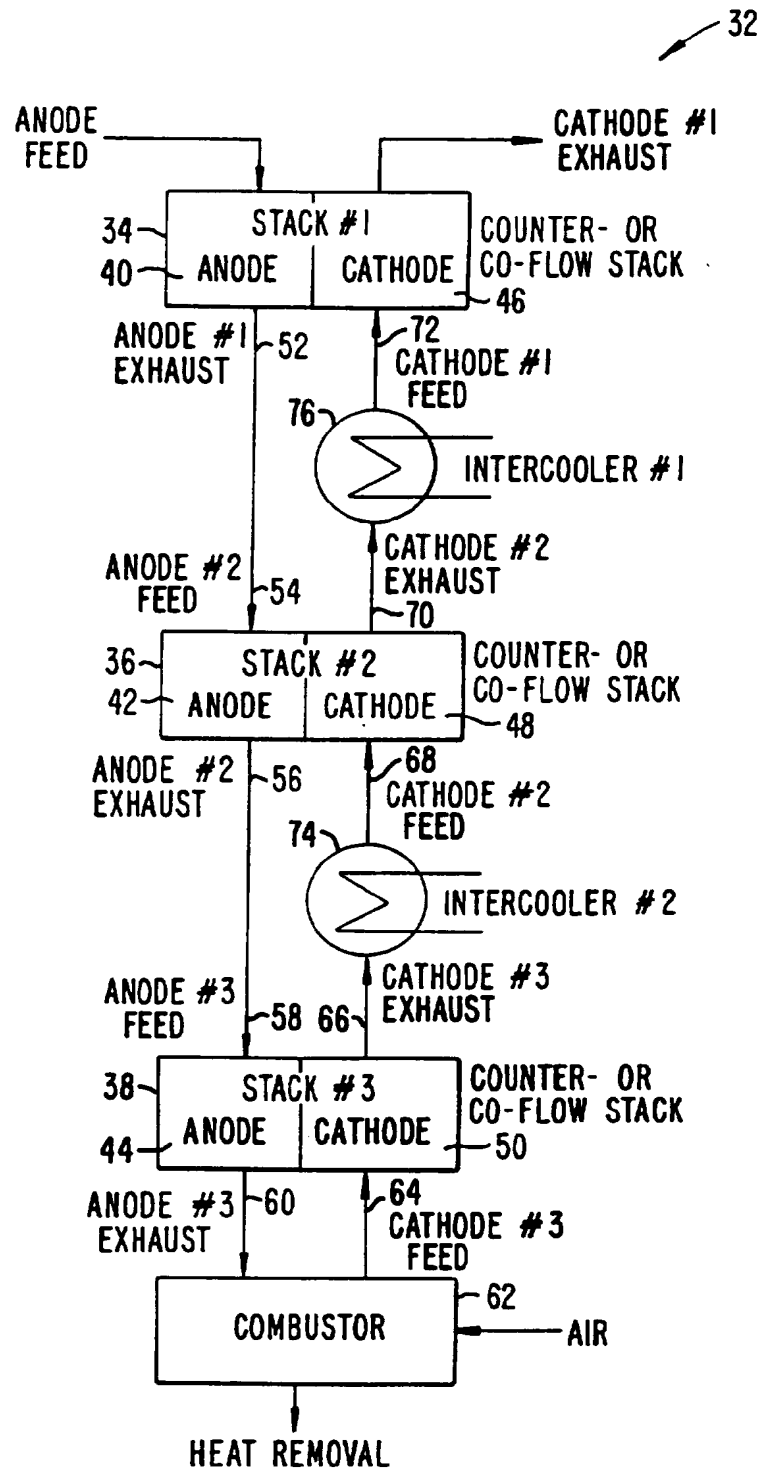
supplying compressed air to the fuel cell to remove sufficient heat from the fuel cell to prevent overheating of the fuel cell, wherein the compressed air is heated prior to supplying the compressed air to the fuel cell, and wherein the compressed air is heated by a heat exchanger receiving gases exhausted from the cathode exhaust outlet.

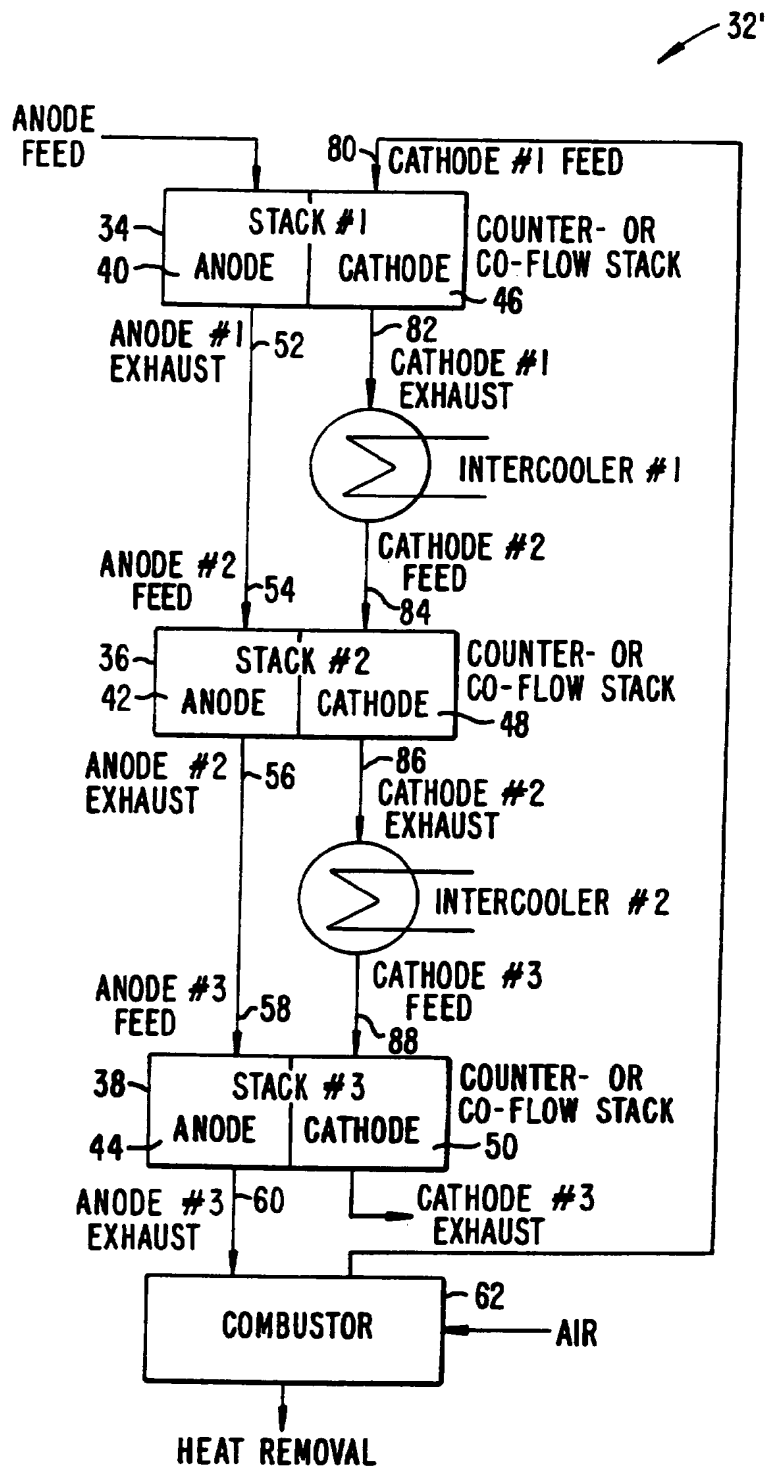
1                   14. The process of claim 13, wherein the supplying  
2 step further comprises channeling the compressed air through  
3 the fuel cell with an intercooler.



**FIG. 1.**  
**PRIOR ART**

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**FIG. 2.**

**FIG. 3.**

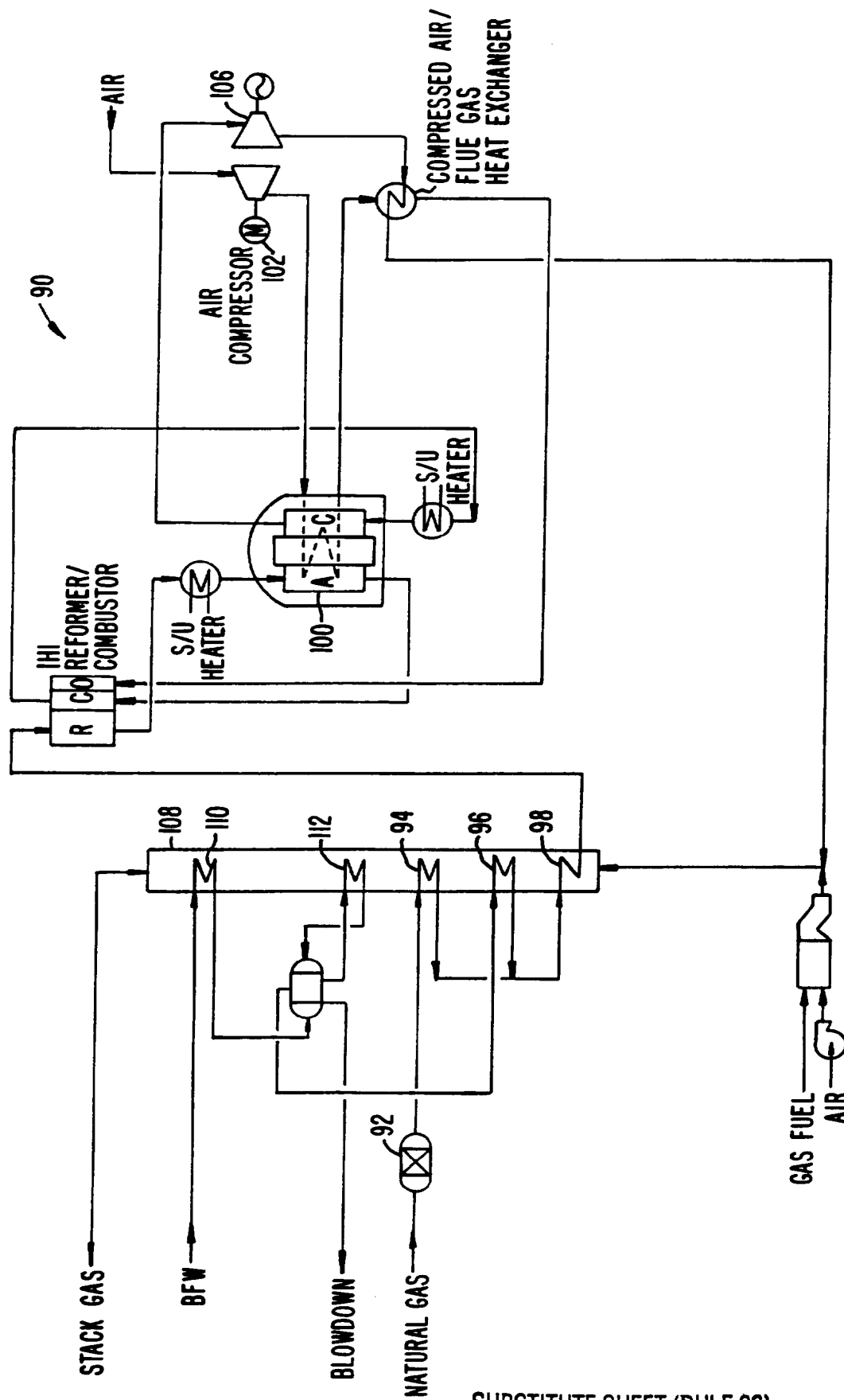


FIG. 4.

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US95/09184**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : H01M 08/04, 08/14

US CL : 429/26, 16, 18

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 429/26, 16, 18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US, A, 5,413,878 (Williams et al.) 09 May 1995	all
A	US, A, 5,100,743 (Narita et al.) 31 March 1992	all
A	US, A, 4,080,487 (Reiser) 21 March 1978	all
A	US, A, 4,722,873 (Matsumura) 02 February 1988	all

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

11 OCTOBER 1995

Date of mailing of the international search report

03 NOV 1995

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